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CASE SERIES

FUNCTIONAL OUTCOMES AFTER DISTAL BICEPS BRACHII REPAIR: A CASE SERIES

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ABSTRACT

Objectives: To investigate outcomes after surgical repair of distal biceps tendon rupture and the influence of arm dominance on isokinetic flexion and supination results.

Background/Purpose: While relatively uncommon, rupture of the distal biceps tendon can result in significant strength deficits, for which surgical repair is recommended. The purpose of this study was to assess patient reported functional outcomes and muscle performance following surgery.

Methods: A sample of 23 participants (22 males, 1 female), who had previously undergone surgical repair of the distal biceps tendon, were re-examined at a minimum of one year after surgery. Biodex isokinetic elbow flexion and supination testing was performed to assess strength (as measured by peak torque) and endurance (as measured by total work and work fatigue). The Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) and Mayo Elbow Performance Scale (MEPS) were used to assess participants' subjectively reported functional recovery.

Results: At a mean of 7.6 years after surgical repair, there were no differences between the repaired and uninvolved elbows in peak torque ($p = 0.47$) or total work ($p = 0.60$) for flexion or supination. There was also no difference in elbow flexion work fatigue ($p = 0.22$). However, there was significantly less work fatigue in supination, which was likely influenced by arm dominance, as most repairs were to the dominant arm, $F(1,22) = 5.67$, $p = 0.03$.

Conclusion: The long-term strength of the repaired elbow was similar to the uninvolved elbow after surgery to the distal biceps tendon. Endurance of the repaired elbow was similar in flexion but greater in supination, probably influenced by arm dominance.

Study design: Retrospective case series

Level of Evidence: Level 4

Key Words: Elbow, endurance testing, flexion, strength testing, supination

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INTRODUCTION

Rupture of the distal insertion of the biceps brachii tendon is a relatively uncommon injury,[1,2] with an reported incidence of 1.2 per 100,000 patients per year.[3] Most of these injuries occur from an eccentric contraction of the biceps brachii, when the flexed and supinated elbow is abruptly loaded.[4,5] Most reported cases have involved middle-aged men[1,2] and the dominant arm is most frequently affected.[6]

It is commonly accepted that surgical management represents the treatment of choice for avulsion of distal biceps tendon, given the deficits reported in the strength and endurance of both elbow flexion and supination associated with conservative or non-operative management.[1,2,5,7] Reattachments of the tendon using the Endobutton and Footprint techniques are two common surgical procedures used for repair after this injury. The Endobutton technique has the advantage of using a single incision, has a low complication rate and provides the strength of fixation to enable early active mobilization.[8,9] The Footprint technique is a new single incision technique, which provides attachment of the tendon to the radial tuberosity.[10]

It is difficult to clearly establish the functional outcomes following surgical repair of the distal biceps tendon avulsion. This is due in part, to the variety of surgical techniques and rehabilitation, variable outcome measures, and methodological challenges associated with case series and small subject numbers.[1,2,5,11,12] Recently in a cohort of 17 patients who underwent a double incision surgical repair and standardized post-operative rehabilitation program, deficits of 10-15% in supination strength and endurance were noted at an average follow up of 24 months.[5] In a review of 26 patients who underwent surgical repair using the Endobutton technique and a standardized post-operative rehabilitation program, ongoing deficits in flexion strength (20%) and supination strength (9%) were noted at a mean of 16 months postoperatively.[13]

Isokinetic dynamometry has been used to assess muscle function following surgical intervention as it is more sensitive than manual muscle testing and is thought to provide a more comprehensive assessment of muscle performance than isotonic or isometric measures.[14] The clinical value of isokinetic testing rests on its reliability, which has been well documented in samples reflective of the general population.[15] The use of isokinetic dynamometry as a measure of post-surgical muscle function has been well established in patients with repaired distal biceps tendons. However, interpreting recovery of muscle function can be complicated by the effect of arm dominance. It is known to have a variable effect, as authors have reported different degrees of dominance, as well as dominance being only evident in specific muscle groups.[1,5,11-13]

A better understanding of the clinical outcomes following surgical repair of distal biceps tendon avulsion is important for evaluating management options. The purpose of the current study was to assess patient reported functional outcomes and muscle performance following two current operative techniques. A secondary purpose was to investigate whether arm dominance influenced muscle performance.

METHODS

Twenty-three participants who had been managed operatively for acute rupture of the distal biceps brachii tendon were recruited between May and August 2015. In all cases, the distal biceps brachii tendon had been repaired by a single surgeon (GB) using the Endobutton[8] or Footprint[10] technique at least one year previously.

Participants self-reported their age, weight, handedness, mechanism of injury, number of days from injury to surgery, and whether they had physical therapy as part of their management. Functional outcomes were measured with the Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH) and Mayo Elbow Performance Score (MEPS) questionnaires. Concentric strength (as measured by peak torque) and endurance (as measured by total work and work fatigue) of the elbow flexors and supinators was tested using an isokinetic dynamometer (Biodex System 4 Dynamometer, Biodex Medical Systems Inc, Shirley, NY). Data were collected using Bioware advantage software (Biodex Applications/operations, Biodex advantage software 4.0) and Spike2 CED software (Cambridge Electronic Design Ltd, Cambridge, England).

The Southern Adelaide Human Research Ethics Committee approved the study (Protocol number 42.15). All participants gave informed consent.

Testing protocol: The Biodex was calibrated in accordance with manufacturer's instructions prior to testing each individual. The system was set-up for testing flexion and supination in the seated position using the manual's guidelines and adjusted to each individual. The limit to motion was set to stop comfortably before full range in each direction. Testing consisted of two tests on each arm, elbow flexion/extension, and supination/pronation. The uninvolved arm was tested before the surgically repaired arm. Participants were familiarized with the angular velocity of the dynamometer and practiced trial repetitions with gradually increasing effort until they were confident with the procedures. A minute's rest was given before each test was started. Participants were given verbal encouragement to give their maximal effort during each test of 50 maximal repetitions at 120°/s. Three investigators (CO, TZ and CR) performed the testing as described below.[16]

Elbow flexion/extension: The chair and dynamometer were each rotated 15° from the base position, and the dynamometer tilt was maintained at 0°. Participants were seated with their upper arm resting on the limb-support (Figure 1). The height and angle of the limb-support was positioned so that the axis of rotation of elbow flexion, passing through the center of the trochlea and capitulum, was aligned with the axis of rotation of the dynamometer arm. Participants were instructed to exert maximal effort in the flexion phase of movement, and to relax during the extension phase. Previous isokinetic testing has involved between three and six repetitions for the evaluation of peak torque[1,5,13] and between 15 and 50 repetitions for the evaluation of endurance.[5,13,17] Previous testing speeds have varied between 30-150°/s for the evaluation of strength,[1,5,13] while testing speeds for endurance have been reported up to 240°/s[7]. This study protocol used 50 repetitions to ensure that fatigue would be experienced during the test and 120°/s was chosen, as it is an intermediate speed, to assess both strength and endurance in a single test.

Forearm supination/pronation: The chair was rotated 60° from the base position and the dynamometer was rotated 30° and tilted downward 5°. Participants were seated and the limb support adjusted so that the axis of rotation of the forearm, (center of the head of the radius proximally to center of the ulna head distally), was aligned with the axis of rotation of the dynamometer (Figure 2). Participants were instructed to exert maximal effort

Figure 1. *Setup for testing elbow flexion/extension.*

Figure 2. *Setup for testing elbow supination/pronation.*

into the supination phase of movement, and to relax during the pronation phase.

The uninjured contralateral arm was used as a matched control without adjusting for an effect of dominance.[18] Strength was evaluated using the value for peak torque in Newton meters (Nm) generated during the 50 repetitions for each test.

Endurance has been evaluated both by total work[5] and work fatigue.[11,12] Total work is the sum of work (in Joules) for all repetitions performed during the test. Work fatigue, is the ratio of the difference, expressed as a percentage between the work performed in the first third of the test to that performed during the last third of the test, expressed using the formula:

$$W_{fatigue} = \frac{W_{first\ third} - W_{last\ third}}{W_{first\ third}} \times 100\%$$

$$W = \text{work}$$

The manual's guide to interpreting results suggests that a deficit percentage within 1-10% indicates that there is no significant difference between muscle groups in strength and endurance measures and a deficit within 11-25% indicate that rehabilitation is recommended to improve muscle balance between the injured and uninvolved sides.

Data analysis: IBM SPSS Statistics for Macintosh, version 23 was used data analysis (IBM Corp., Armonk, N.Y., USA). Data were summarized descriptively. Variables were expressed as means (95% confidence interval) or median (range), according to their distribution. The biceps function of the repaired and uninvolved arms was compared using paired t-tests. This analysis was for both strength and endurance in flexion and supination. A two-way ANOVA was conducted that examined the effect of surgical repair and arm dominance on muscle function. The probability level of 0.05 was set as the standard of statistical significance for all analyses.

RESULTS

Participants: The median age was 57 years (range 42-79). All participants were male except one. The mechanism of injury involved a sudden eccentric load associated with falls, heavy lifting at work, or during recreational sporting activities. Surgery involved the dominant arm in 70% (16/23) of cases and 65% (15/23) had received physical therapy during their recovery. Isokinetic testing was performed at a mean of 7.6 years after surgical repair, at which stage all participants had achieved good to excellent recovery based on their functional scores. The median QuickDASH score was 2.25, range [0-29.5], where 0 indicates no functional limitations. The median MEPS score was 100, range [80-100] where a score of 100 indicates full function.

The participant characteristics are presented in Table 1.

Isokinetic outcomes

Strength

The mean peak torque (Nm) for elbow flexion in the surgically repaired arm was not significantly different from the uninvolved arm ($p = 0.47$). The mean peak torque for supination of the surgically repaired arm was also not significantly different from the uninvolved arm ($p = 0.75$).

Endurance

The mean percentage of work fatigue for flexion (49%) for the surgically repaired arm was not significantly different from the uninvolved arm (45%, $p = 0.22$). The mean percentage of work fatigue for supination (12%) for the surgically repaired arm was significantly less than for the uninvolved arm (23%, $p = 0.046$).

The total work performed (J) over the 50 repetitions by the surgically repaired arm was not significantly different from the uninvolved arm for flexion ($p = 0.60$) or for supination ($p = 0.75$). The isokinetic results are presented in Table 2.

Figure 3 displays an example torque tracing from the four tests for Subject 8, who was right arm dominant. It illustrates how work fatigue percentages will be reduced if the biceps muscle is sub-maximally activated at the start of a test, or if there are fluctuations in effort during a test. The top two tracings are for the flexion tests and show that the peak torque generated by the repaired dominant right arm occurred later, on repetition 31. The peak torque (N.m), total work (J) and work fatigue (%) were less than for the uninvolved left arm. The lower two tracings are for the supination tests and show that there were

Table 1. *Participant characteristics and self-assessed outcomes*

Case	Mechanism of injury	Age	Dominance L / R	Injury L / R	Follow-up (years)	Quick DASH	Pain (VAS)	MEPS	Recovery (self-assessed)
1	Fall whilst water skiing	54	Right	Right	5	0	0	100	100%
2	Heavy lifting	56	Right	Right	9	4.5	0.5	100	85%
3	Heavy lifting - industrial	46	Right	Right	7	4.5	1.5	100	85%
4	Fall from ladder	79	Left	Left	9	0	0.5	95	75%
5	Stopping a sheep - farming	75	Right	Right	8	29.5	1.5	100	85%
6	X	43	Right	Left	9	6.9	X	95	X
7	Catching a partner – martial arts	44	Right	Left	6	0	0.5	100	95%
8	Golf swing	72	Right	Right	8	27.3	0.5	80	95%
9	Heavy lifting – structural steel	68	Right	Right	10	4.5	0	100	100%
10	Heavy lifting – landscaping rocks	65	Right	Right	5	4.5	0	100	X
11	Catching a partner – dancing	69	Right	Right	8	9.1	0.5	100	95%
12	Stopping playground equipment	62	Right	Left	8	0	0.5	100	95%
13	Heavy lifting	48	Right	Right	11	0	0	100	100%
14	Water skiing take off	59	Right	Right	8	0	0.5	100	95%
15	Cricket swing	50	Right	Right	10	6.8	0.5	100	85%
16	Cricket swing	42	Right	Right	5	0	0.5	100	75%
17	Lifting child	53	Left	Left	5	0	0.5	100	95%
18	Lifting a heavy lounge	47	Right	Left	6	0	0.5	100	95%
19	Supporting own body weight	60	Right	Left	6	0	0.5	100	95%
20	Catching patient – health care	49	Right	Right	6	0	0.5	100	95%
21	Water skiing take off	63	Right	Right	11	2.3	X	100	X
22	Preventing a slip / fall	57	Right	Left	7	15.9	2.5	85	55%
23	Grinding the winch – sailing	59	Right	Left	5	0	0.5	100	85%
	Median (range)					2.25 (0-29.5)		100 (85-100)	95(55 – 100)

Key: DASH Disabilities of the Arm, Shoulder and Hand; VAS Visual Analogue Scale; MEPS Mayo Elbow Performance Scale; X=missing data

Table 2. *Isokinetic results from flexion and supination tests of 50 repetitions at 120°/s (n = 23).*

	Repaired		Uninvolved			
Flexion	**Mean**	**95% CI**	**Mean**	**95% CI**	***Mean difference***	***p-value***
Peak torque (N.m)	40	34.5, 45.5	38.9	34.4, 43.3	1.1	0.47
Work fatigue (%)	49.4	43.0, 55.7	44.7	38.1, 51.4	4.6	0.22
Total work (J)	1545	1331, 1760	1516	1308, 1724	29.5	0.60
Supination						
Peak torque (N-M)	8.4	7.4, 9.4	8.6	7.5, 9.6	-0.2	0.75
Work fatigue (%)	12.1	4.6, 19.6	22.9	14.1, 31.7	-10.8	0.046
Total work (J)	410	317, 502	390	322, 459	19.2	0.75

M= mean; CI=confidence interval; Nm= Newton-Meters; J= Joules

more fluctuations and spikes in the torque generated by the dominant right arm during the trial. This resulted in less peak torque (N.m) and work fatigue (%) but more total work (J) than for the uninvolved left arm.

Repair of dominant versus non-dominant arm

A two-way analysis of variance examined if the effect of surgical repair of the biceps tendon on strength and endurance varied depending on whether the dominant or non-dominant arm was repaired. Arm dominance

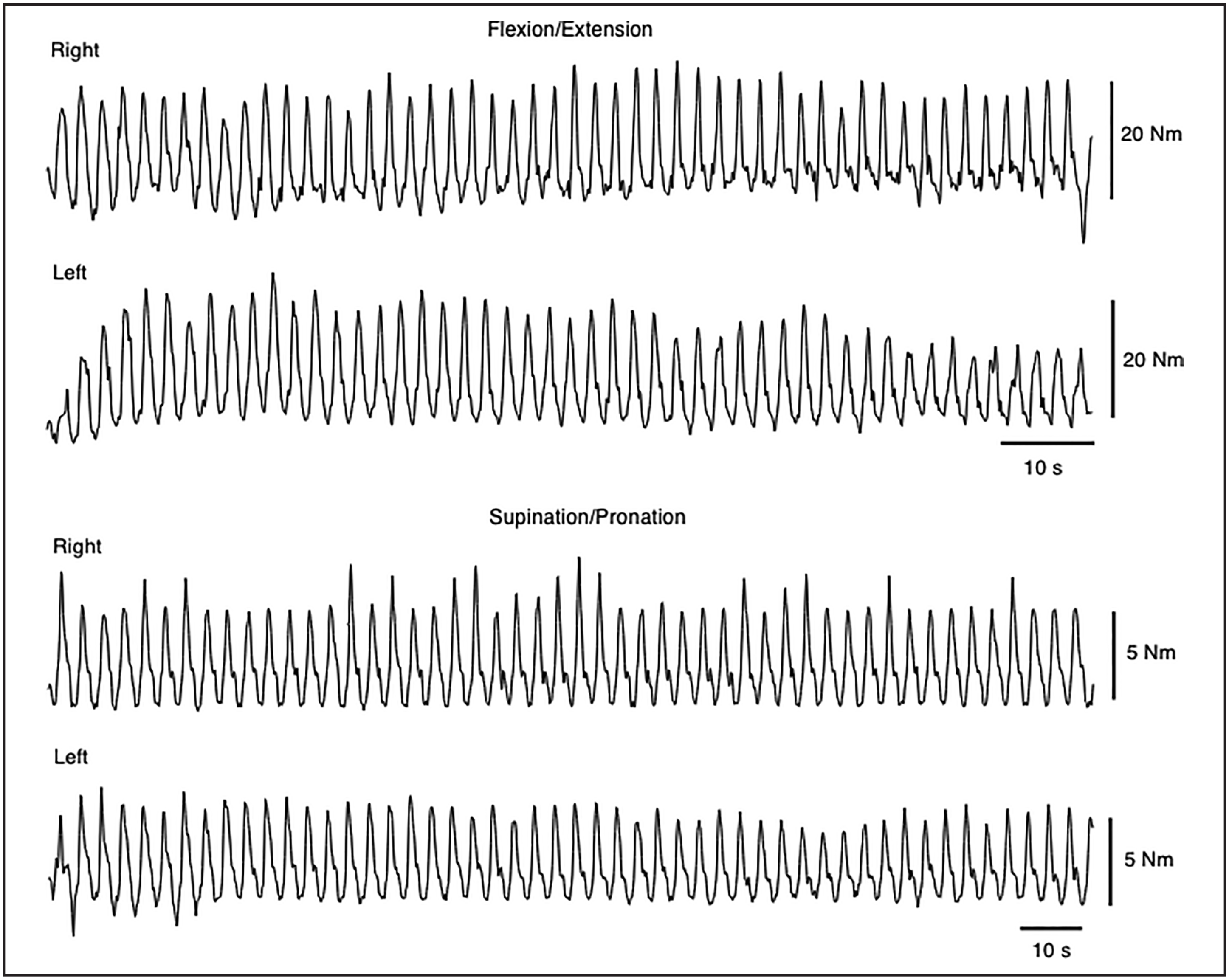

Figure 3. *Graph of torque tracing for Subject 8, which shows greater fluctuations in effort by the repaired dominant right arm (seen as spikes in torque output for right elbow flexion/extension and supination/pronation during the 50-repetitions).*

had a statistically significant effect on work fatigue in supination, $F(1,22) = 5.67$, $p = 0.03$, suggesting that the dominant arm (mean = 12.0%, $SD = 16.0\%$) fatigued less than the non-dominant arm (mean = 23.0%, $SD = 21.3\%$). Partial eta squared = 0.21. This is a moderate effect. The interaction between surgery and arm dominance was not significant.

In contrast to the results for work fatigue in supination, the dominant arm did not significantly affect the results from the other strength and endurance measures. The strength of the dominant arm was similar to the non-dominant arm in both flexion and supination and the endurance of the dominant arm was similar to the non-dominant arm in flexion.

Association between physical therapy and outcomes

Physical therapy was not associated with isokinetic results for flexion ($p = 0.42$) or supination strength ($p = 0.63$), or MEPS scores ($p = 0.20$) but was associated with better QuickDASH scores ($p = 0.04$).

DISCUSSION

The patients in this series who had undergone a surgical repair of the distal biceps tendon had excellent recovery of strength in flexion and supination at a minimum follow up of one year. This compares favorably with deficits in flexion[13] and supination strength[5,11-13] reported in other case series and may reflect that the follow-up in this case series ranged up to eleven years. As expected, elbow flexion peak torques were observed to be greater than supination peak torques, reflecting differences in leverage and cross-sectional area of the muscles involved, both of which relate to a muscle's ability to generate torque.[19]

Two measures were used to assess biceps muscle endurance. These were total work, which is the sum of work from all repetitions performed during the test and work fatigue, which is a measure of the ability to maintain maximal muscular effort over a sustained period. Of the two measures, work fatigue provided interesting results, by revealing a difference that was likely as a result of arm dominance. The authors identified that the rate of fatigue for flexion was similar between the repaired arm (mean, 49%) and uninvolved arm (mean, 45%). In contrast, the work fatigue for supination was different between the repaired arm (mean, 12%) and the uninvolved arm (mean, 23%). This result was affected by whether the dominant arm or non-dominant arm was repaired. Participants who had surgery on their dominant arm demonstrated greater endurance in supination than those who had surgery to their non-dominant arm. Arm dominance had a variable effect, and influenced supination but not flexion, which may reflect differences in the coordination required for these movements, as supination is more of a fine motor skill.

The dominant arm may have greater endurance, or alternatively, fluctuating effort during the 50-repetition trial may have been a factor that contributed to lower rates of fatigue. Fluctuations in effort by the repaired arm during the supination test are illustrated by representative torque data from Subject 8 in Figure 3. This subject was one of the few subjects who had ongoing functional limitations (QuickDASH = 27.3). The torque tracings illustrate intermittent spikes in the amount of torque produced when the repaired arm was tested. Poor motivation or confidence, pain, deficits in neuromuscular control, ineffective stabilization of the arm[20] or different characteristics of the muscles involved in flexion and supination[5] are all factors that may contribute to fluctuations in performance.

Patient-reported functional outcomes in the current study, assessed by the QuickDASH and MEPS scales, indicated that function was good to excellent in all subjects. These results are consistent with other authors who have reported good to excellent functional outcomes after operative repair.[5,13]

The difference in work fatigue seen in supination has implications for testing and interpreting supination/pronation movements with isokinetic equipment. If patients feel less confident when the repaired arm is tested, it may be advisable to use repeated measurement, as muscle performance may improve over short periods of time with practice.[21] It also has implications for rehabilitation, as muscle is highly adaptable and responds to training through hypertrophy and neural adaptations. Training to improve neuromuscular control should be incorporated into rehabilitation programs, once adequate strength is restored. Neuromuscular control is improved by prescribing exercises that gradually increase the challenge through varying load, repetition and speed for individual strength-endurance needs.[22] Neural adaptations include increased neural output from the CNS and improved motor unit recruitment and synchronization.[23]

The present study has added to the literature by exploring the influence of arm dominance on post-operative measures of strength and endurance. It has previously been suggested that rehabilitation may benefit patients with non-dominant distal bicep tendon repairs, to counteract a preference for using their dominant arms for activities of daily living. Previous case series have found that patients with repairs of the non-dominant arm had long-term deficits in supination strength,[11,12] while those who underwent repairs of the dominant arm had deficits in flexion endurance.[11] In contrast, we found that the repaired dominant arm had greater endurance in supination but similar results to the repaired non-dominant arm in flexion.

Given that the results from various studies are conflicting, referral to physical therapy should not be based on whether the dominant or non-dominant arm was repaired. In addition, the results from the current and prior studies,[5,13] have shown similar long-term recovery of strength, regardless of whether post-operative rehabilitation was provided. However, there is still a need to understand if rehabilitation benefits recovery in the shorter term. Physical therapy may be indicated when recovery of movement is inhibited by ongoing pain, in order to assist individuals to return to sport or occupations with high demands for physical function,[9] to prescribe specific exercises to enhance neuromuscular control, or to assist patients in regaining confidence to return to normal activities.

Currently there is little information to justify different rehabilitation protocols in the early post-operative period. Protocols for the first few months after surgery are influenced by fixation methods[6] and initially aim to protect the repair. The protocol used with patients in this series was for unsupervised post-operative recovery. This consisted of advice given at one to two weeks postoperatively, to gradually discontinue the sling, begin active range of movement and resume restricted, light activities for a period of three months, before returning to unrestricted activity, including heavy lifting.[8,9] Although this protocol does not include routine referral to physical therapy, the 65% of the subjects in this case series who accessed physiotherapy services may have been self-referred or referred by the surgeon or other health professionals.

Several limitations may affect this study. Long-term outcomes were examined using a case series, which limits the ability to generalize from the findings. Prospective studies are needed to examine functional recovery in the immediate post-operative period, so physical therapy practice is better informed. In addition, there is a need for further research to determine the reliability of isokinetic testing in clinical populations, and the optimal parameters for measuring endurance.

CONCLUSION

Full recovery of isokinetic flexion and supination strength and good to excellent functional abilities was obtained following distal biceps tendon repair in 23 subjects. Arm dominance had an effect on the results, in that patients who had surgery on their dominant arm demonstrated better endurance in supination than those who had surgery on their non-dominant arm.

Additional research is warranted to study patients who have undergone distal biceps tendon repair that evaluates the expected trajectory for the recovery of strength and endurance and to provide further guidance on the optimal, specific exercise parameters for rehabilitation.

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